Communication Document

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Field Test Implementation of Queue Control

WHY WAS THIS RESEARCH UNDERTAKEN?

This study was sponsored by the California Department of Transportation as the first stage of a ramp metering with queue control field study. The field test has been proposed in order to implement ramp metering with queue estimation and regulation on the Hegenberger Rd. Loop on-ramp to 880 southbound in the Caltrans Bay Area District to study its effect in minimizing queue and mainline density oscillations and enhancing performance. The field study was designed to be completed in three stages. In the first stage, different queue estimation methods were evaluated. The use of accurate queue estimation algorithms in freeway on-ramp metering may improve on-ramp storage utilization and reduce queue spillover into the adjacent arterials.

WHAT WAS DONE?

A major challenge for implementing queue control has been to accurately estimate on-ramp queue lengths, particularly during saturated on-ramp conditions, when the vehicle queue extends around or beyond the ramp entrance. The main outcome of TA-65A0320-15354 was the development and field test verification of an accurate on-ramp queue length estimation algorithm, which performs reliably even under severe on-ramp saturated conditions.

Four different vehicle queue length estimation methodologies were studied using wireless magnetic sensors installed on a single lane loop on-ramp in District 4. Queue length estimation based on (i) occupancy measurements at the ramp entrance, (ii) vehicle counts at the on-ramp entrance and exit, (iii) speed measurements at the ramp entrance, and (iv) vehicle re-identification were considered. The accuracy and reliability of the queue estimation methods were studied using ground truth data obtained from video.

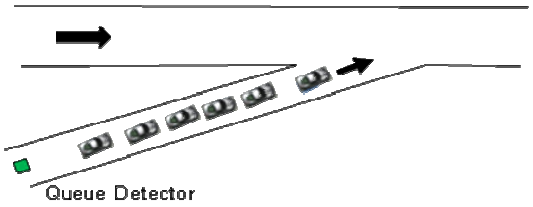
Except for the vehicle queue estimation method based on a modified vehicle re-identification algorithm, all tested methods exhibited subpar performance under saturated on-ramp conditions to the extent that they cannot be used to reliably estimate on-ramp queue lengths.

Based on the observations at the on-ramp test site, it was also possible to point out some of the main factors that affect the performance of the different queue estimation methods considered for this project.

RESULT OF THE RESEARCH

Occupancy Queue Estimation

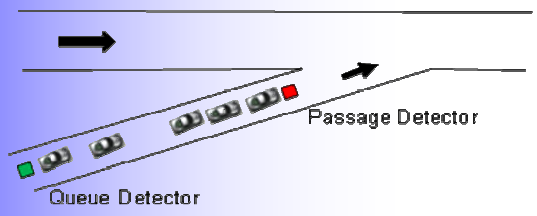
This method corresponds to the queue estimation method used with queue override. It consists of determining if the queue is at or beyond the queue limit by comparing the occupancy measured at the entrance of the ramp with an occupancy threshold.



This method may be used to determine if the ramp is either empty or full, but it cannot be used to estimate the queue length accurately. This approach is highly dependent on the time calculation interval over which occupancy is calculated, and under on-ramp saturated conditions may yield misleading results due to vehicles' tendency to miss sensor detection zone.

Vehicle Counts Queue Estimation

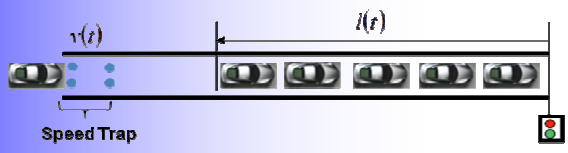
This method counts vehicles entering and leaving the on-ramp. The difference between the counts gives the queue length, provided the initial number of vehicles at the ramp when the counting is initiated can be accounted for.



This is not an acceptable method to estimate the queue due to its inability to correct for errors like detector miscounts and offsets resulting from initial conditions.

Queue Estimation Based on Speed

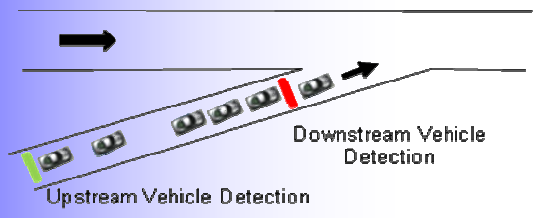
This method assumes it is possible to accurately calculate queue length, $l(t)$, from vehicle speed measurements at the entrance of the on-ramp, $v(t)$.



The speed based queue estimation method seems to be capable to instantaneously determine the mode of the on-ramp vehicle queue: unsaturated, saturated, or in transition. Unfortunately, based on the results obtained, this queue estimation approach is not suitable to reliably estimate queue lengths.

Vehicle Re-Identification Queue Estimation

This scheme is based on matching individual vehicle signatures obtained from wireless magnetic sensor arrays placed at the two ends of the on-ramp. It relies upon counting vehicles entering and leaving the on-ramp and corrects for errors using the vehicle re-id algorithm.



This method performed better that the other three methods, but it under-performed in estimating queue lengths during saturated on-ramp conditions. This was due to the fact that the vehicle-matching rate was very low during congestion. As a consequence of the original results obtained, a modified vehicle re-identification algorithm was formulated and tested. With the new re-id algorithm, the vehicle matching rate was significantly increased. A higher matching rate allows for a better and rapid correction of errors in the queue estimate. With the improved vehicle re-identification algorithm, the error remains bounded and the queue estimate is able to track the ground truth queue length with sufficient accuracy, even under congested on-ramp conditions.

WHAT DO THE RESEARCHERS RECOMMEND?

Vehicle queues at on-ramps can be accurately estimated using vehicle counts and a correction mechanism based on re-identifying vehicles. This type of queue estimation could be implemented with the use of video cameras, loop detectors, Bluetooth technology, among others, as long as the vehicle re-id system is able to count vehicles and re-identify vehicles in real time with sufficiently high accuracy and frequency.

IMPLEMENTATION STRATEGIES

In this project, we used the Sensys vehicle detection system and re-id algorithm to estimate the queue length at the on-ramp. However, the queue estimation method based on vehicle re-id may not be Sensys-specific. It may be beneficial for Caltrans to explore the use of vehicle re-identification algorithms using the loop detectors that are already installed in the on-ramps, since this would reduce the cost required to implement this on-ramp queue estimation methodology throughout California.

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